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SUBMISSION OF PROPOSAL FOR TOPIC APPROVAL

PROPOSAL FOR TOPIC APPROVAL TO BE SUBMITTED TO THE **UNIVERSITY OF MUMBAI**

FOR THE **PH.D. DEGREE IN THE SUBJECT OF CHEMISTRY**

Title of topic	:	**Synthesis and Catalytic Activity Study of Transition Metal Complexes of Substituted Porphyrins by Conventional and Flow Chemistry**
Name of the student	:	MR. ASHISH M. UJAGARE
Basic Qualification	:	MSc(Organic Chemistry)
In the case of Ph.D. student Year of Passing Of PET / NET SET /GATE / M. Phil (Teaching Experience)	:	PET (April 2021)
Name of the Research Supervisor/ Guide	:	Dr. Kamini J. Donde
Date of Superannuation / Retirement	:	31-03-2037
Name of the Research Centre	:	Ramnarain Ruia Autonomous College, Mumbai : 400019
Signature of the Student	:	
Signature of Research Supervisor/ Guide	:	

Date :

Seal of College/ Department

Head/Director/Principal
Research Centre

Principal
Ramnarain Ruia Autonomous College
Matunga, Mumbai - 400 019.

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RESEARCH PROPOSAL

Outline of the proposed work to be carried out by **Ashish M. Ujagare** for the degree of **Doctor of Philosophy (Ph.D.)** in Chemistry under the guidance of **Dr. Kamini J. Donde**

1. Title:

Synthesis and Catalytic Activity Study of Transition Metal Complexes of Substituted Porphyrins by Conventional and Flow Chemistry

2. Aim of Study

Porphyrins are known to have extremely high coordination ability. As a result, porphyrins have been intensively studied recently as ligand for various metal ions. The catalytic activity of the metal ion has also been enhanced after binding with porphyrins. Despite of this, a very few reports on the use of porphyrins-metal complexes as a catalyst for various organic reactions have been reported. Also, these porphyrins-metal complexes are not applied in flow chemistry.

Therefore, the aim of this proposed research work is the synthesis of various substituted porphyrins and their metal complexes which will be having high catalytic activity, high thermal stability and that can be applied in flow chemistry. The catalytic activity will be investigated by carrying out C-C coupling reactions. Effect of substituents on catalytic activity will be studied. Synthesis process and reaction catalyzed by the complexes will be also studied in flow reactors, intensification of reactions is expected in the flow reactors.

3. Objectives of Study

The proposed research work has following objectives;

- To synthesize the substituted porphyrins containing monomers using octyloxy substituted phenyl)-dipyrromethane.
- To study metal binding property of these porphyrins by introducing the transition metal ions like Copper, Nickel and Palladium.

- To investigate the molecular structure of these substituted porphyrins.
- To investigate the molecular structure of these metal complexes of substituted porphyrins.
- To study their solubility, conductivity, XRD, SEM, spectral and thermal properties.
- To study their electrochemical behavior of porphyrins and metal complexes.
- To study catalytic activity of metal complexes and effect of substitution on the catalytic activity.
- To study application of metal complexes in flow chemistry by improved synthesis and applications by process intensification.

4. Study Background (Literature Review) and Significance of Study:

Porphyrin is an organic compound that contains four pyrrole rings. Pyrrole is a pentagon-shaped ring of four carbon atoms with a nitrogen atom at one corner (C_4H_5N).The porphyrins are actually an enormous group of organic compounds, found all over the living world. The special thing about porphyrins is that they bind to metals. The four nitrogen atoms placed in the middle of the porphyrin molecule act as teeth: they can grab and hold metal ions such as magnesium (Mg), iron (Fe), zinc (Zn), nickel (Ni), cobalt (Co),copper(Cu),and silver(Ag).

Porphyrins and their derivatives have been intensively studied for many years because of their importance in the photochemistry and photo-biology processes. Porphyrins are tetrapyrrolic macrocycles and have a special structure with a big p-orbital on the carbon–nitrogen framework [1-3]. Under the influence of the large planar p-conjugated structure, porphyrin derivatives exhibit good thermal stability, strong two-photon absorption [4], efficient electron transfer [5], and interesting photo-electrochemical properties [6]. Therefore, porphyrins have been frequently employed in some fields such as biomimetic catalysis [7], chemical and biological sensors [8], organic light-emitting diodes [9], field effect transistors [10] and solar cells [11]. Recently, porphyrin derivatives have been studied as favorable photosensitizers in photovoltaic cells. For example, Campbell et al. synthesized one kind of dark green porphyrin sensitizers with the highest power conversion efficiency (PCE) of 7.1% in dye-sensitized solar cells (DSSCs) [12].

Porphyrins are biochemically important, medically useful, and synthetically interesting compounds. Porphyrins that occur naturally play a major role in the life sustaining biochemical reactions. They are a ubiquitous class of compounds with many important biological representatives including hemes, chlorophylls, myoglobins, cytochromes, catalases, peroxidases, and several others. Used by nature in the most important processes of photosynthesis and solving transport and other problems in living systems, these compounds have been described as 'Pigments of Life'. Their aromatic character, inner chelating pocket and varying peripheral carbon chains have allowed scientists to discover new and unique chemical reactions. Porphyrins and their metal complexes have also stirred interdisciplinary interest due to a multitude of their intriguing physical, chemical and biological properties. Porphyrin and their metal complexes showed excellent catalytic properties [1,2]. Hence we decided to synthesize various porphyrin and their metal complexes to study their property and explore their application in catalysis of various organic reactions. We also intend to explore use flow chemistry in their synthesis and application.

5. National Status

There are recent references for synthesis and applications of porphyrin metal complexes. The research group of Sankar at IIT, Roorkee has synthesized Ni –complexes of porphyrin. The Ni complex prepared found its application in sensing technology [13].

Also recently large scale green synthesis of porphyrin moiety is reported recently by Mondal et al [14].

However there is no report on synthesis and application of porphyrin and its metal complexes using flow chemistry.

6. International Status

Various publications in the year 2021 relating to porphyrin indicate its moiety of immense scientific interest, having varied applications. The applications include medicinal chemistry [15], sensors [16] and light harvesting i.e. converting light energy of Sun to electricity [17].

7. Study Hypothesis

It is also reported that, the efficient porphyrin shows high coordination ability towards the transition metal ions. If transition metal ion is introduced into the porphyrins, then optical properties, catalytic activity and other properties porphyrins get enhanced. The porphyrins are highly stable, and insensitive to moisture and air, their transition metal complexes will have catalysis applications in various applications such as reported for other porphyrin-based complexes in C-C coupling reactions [18- 23]. Past four decades have witnessed the remarkable discoveries that have greatly boosted the synthetic chemistry by the use of transition-metal catalyzed cross-coupling reactions that play tremendous role in the construction of new carbon-carbon bonds [24]. Recently, palladium(II)-porphyrin catalytic system has been developed for the Mizoroki-Heck coupling of aryl bromides with alkyl acrylates under mild conditions. These complexes showed better activity in the present conversion. This finding has significant advantages like operational simplicity, easy synthesis of porphyrin ligands and their complexes with palladium, utilization of safer and recyclable catalyst and high yields of C-C coupling products [25]. Most of these ligands are less toxic, economical and shows high thermal stability, resistance to moisture and air and high coordinating ability to transition metal ions. Recently, transition metal complexes have been synthesized using flow chemistry.

8. Study Rationale

Based on the reports discussed in study hypothesis; to the best of our knowledge there are few reports available on the use of porphyrin-based ligands as a catalyst for the organic coupling reactions [25] and also no report was available on the use of flow chemistry in synthesis of porphyrin-based transition metal complexes.

Therefore, our initial objective is to design and synthesize substituted metal binding porphyrins. Several synthetic strategies will be employed to achieve the synthesis of the target compounds including synthesis and application using flow chemistry [25-26]. The catalytic activities of these compounds will be studied on several organic carbon-carbon coupling reactions.

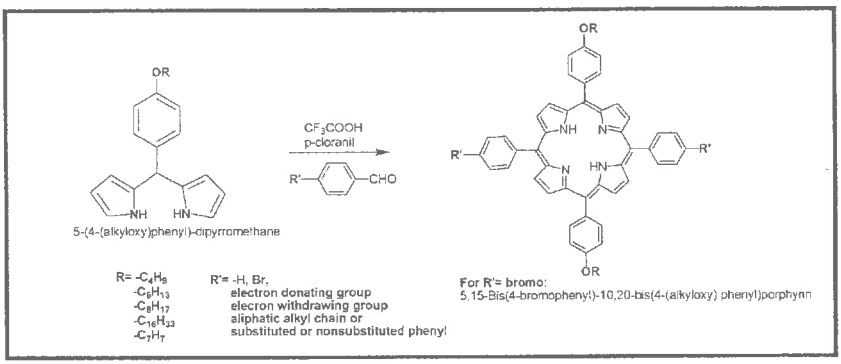
9. Research Methodology

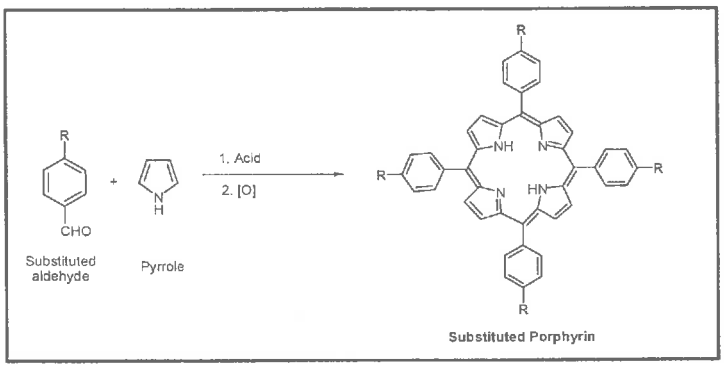
Various substituted porphyrins and their metal complexes will be synthesized using various transition metal ions as per the following work plan.

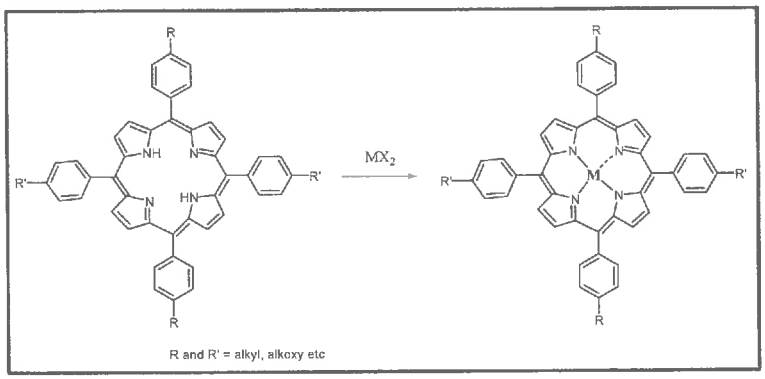
General procedure of Porphyrins

Reaction of alkyloxy substituted phenyl-dipyrromethane and 4-substituted benzaldehyde will be carried out as per the literature protocol. Alternatively the synthesis will be carried out by Lindsey method using substituted aldehyde and pyrrole. The porphyrins obtained will be purified by flash column chromatography.

Different derivatives of porphyrin will be synthesized by changing various substituents that are known as well as not known in the literature [14]. A general reaction can be shown as follows;







The metal binding property of these porphyrins will be studied by introducing the transition metal ions into the main ring of the porphyrins moiety. The structural characterization of the porphyrins and metal complexes to be synthesized will be done on the basis of their melting point, solubility, elemental analysis, conductivity study, LCMS, FTIR spectra, NMR spectra, X-ray diffraction, Scanning electron microscopy, UV-visible spectroscopy and Photoluminescence spectroscopy. The thermal stability will be done by TG-DTA analysis. Electrochemical behavior of these porphyrins will also be studied.

Catalytic activity study: The transition metal complexes of substituted porphyrins will be employed for various carbon-carbon cross coupling reactions such as Heck, Suzuki and Sonogashira reactions.

Application in flow chemistry: These transition metal complexes will also be employed in the organic reaction carried out in flow reactors to study the enhancement of their efficacy and stability while catalyzing synthetic organic reactions by process intensification. Reactions carried out in Flow reactor have unique advantages over batch process, owing to turbulent mixing, residence time and precise control of temperature and pressure. Also the reactions carried out in flow reactor are continuous processes, which are industrially important due to no downtime and more productivity. Therefor reactions catalyzed Metal-Porphyrin will be carried out in conventional batch set up as well as in flow reactor. The results will be compared and process would be fine-tuned by decreasing the catalyst loading thereby making it more efficient, green and economical, thus reducing the 'Carbon Footprint'.

Materials and methods:

The instruments, chemicals, glass wares to be used are described as follows. Some of the instruments listed below are available in the Department of Chemistry, University of Mumbai as well as at collaborating lab at Arch Pharmalabs Ltd, Mumbai that can be made available on request through proper channel.

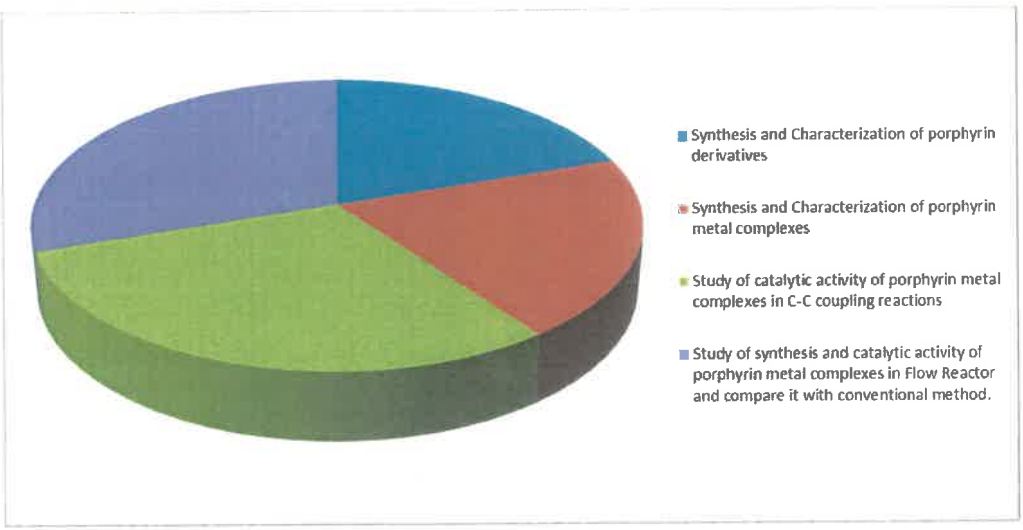
Chemicals	:	All chemicals used will be of AR and LR grade quality.
Glassware	:	All glasswares used will be of pyrex, borosil, corning glass.
UV-Visible Spectrophotometer	:	Shimadzu – 2100
Spectrofluorophotometer	:	Shimadzu – RF-530/PC
FTIR Spectrophotometer	:	Spectrum One (Perkin Elmer)
NMR Spectrophotometer	:	Bruker 300 Avance ^{I}, 300 MHz
LCMS	:	Agilent LC-MS
GPC	:	Perkin Elmer Series 200-RI Detector GPC
Conductometer	:	Elico-Conductivity Meter CM 180
pH-Meter	:	Elico-India, LI 120
TG-DTA-DSC Assembly	:	Perkin Elmer / Pyris Diamond
C H N Analysis	:	Euro Vector EA – 3000
Digital Balance	:	Con Tech Precision Balance CA Series
Electric Hot Plates and Oven	:	Lab Hosp Oven (Digital)
Thermostat	:	Classic Scientific Constant Temp Bath
Flow Reactor	:	MakSpeedNeutron Reactors 10 ml size (SS and Hastelloy).

Double distilled water will be used throughout the experiments.

10. Statistical Plan

The study will be divided in four different parts;

1. Synthesis and Characterization of porphyrin derivatives
2. Synthesis and Characterization of porphyrin metal complexes
3. Study of catalytic activity of porphyrin metal complexes in C-C coupling reactions
4. Study of synthesis and catalytic activity of porphyrin metal complexes in Flow Reactor and compare it with conventional method.


Synthesis and Characterization of porphyrin derivatives
Synthesis and Characterization of porphyrin metal complexes
Study of catalytic activity of porphyrin metal complexes in C-C coupling reactions
Study of synthesis and catalytic activity of porphyrin metal complexes in Flow Reactor and compare it with conventional method.

11. Limitations of the Study

The study is limited to the synthesis and applications of porphyrin derivatives and their metal complexes with transition metals. It does not involve any other N-heterocycle coordination complexes.

12. Expected results / outcomes:

It is expected that, the porphyrins and their metal complexes to be synthesized may show following results;

- Substituted Porphyrins will possess both excellent coordination ability and thermal stability.
- Depending upon their catalytic activity, these metal complexes of substituted porphyrins will be useful as catalyst for various organic reactions.

- Flow chemistry will be employed in synthesis of metal complexes of substituted Porphyrins and their application in various organic reactions with enhanced efficacy and stability.
- Transition metal complexes of substituted porphyrins may show excellent electrochemical behavior.

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